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The Results of Shaping the Blade of a Knife

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ABSTRACT: In this work are given results of shaping of the blade at the expense of crossing of microreliefs of lateral surfaces, and on microgeometry influencing not only technological parameters of sharpening, but also physical and mechanical properties of a material, and also the forces arising in the sharpening process.

KEYWORDS: edge blade, a microrelief, sharpening, microgeometry, the lamellar knife, a cutting edge, a thickness of an edge, hardness, roughness of a cutting edge, a micro tooth.

I.INTRODUCTION

The formation of the blade occurs due to the intersection of the microreliefs of the side surfaces (chamfers), and the microgeometry is influenced not only by the technological parameters of the sharpening, the physical and mechanical properties of the material, as well as the forces arising in the process of sharpening, and their direction. Testing the significance of the various factors that comprise the shaping of the blades was carried out by dispersion analysis [1].

II. SIGNIFICANCE OF THE SYSTEM

Test results knives, blanks which are made of steels У8А,65G,85ХФ and having a hardness corresponding to HRC 48-52 units in particular, have shown that the material has virtually no effect on the performance of surface geometry. Therefore, in a preliminary series of experiments to study factors were studied: the angle, the direction of grinding, the grain size of the circle. Analysis of the resulting regression equation shows that the angle and direction of sharpening slightly affect the microgeometry of the blade. The greatest influence is the grain of the abrasive wheel. Based on the results of experimental measurements of the surface geometry of the blades of the distribution curves of R_{max} and S for a single knife is similar to the normal distribution curves, which confirms a homogeneous pattern of random effects independent of the primary factors in the absence of a sharply dominating [2].

III. LITERATURE SURVEY

The results of preliminary experiments and analysis of literature data [3,4,5] allow to accept as the most significant factors affecting the microgeometry of the cutting edge, the characteristics of the abrasive wheel (grit and hardness); sharpening mode (longitudinal feed), the hardness of the workpiece material. The aim of the main series of experiments was to obtain a mathematical model of the sharpening process, describing the influence of numerical factors on the cutting edge microgeometry. This series of studies also used methods of mathematical planning of the experiment. Selection of levels and intervals of variation of factors (table.1) was made on the basis of literature data and the results of preliminary experiments.

Table.1.

Planning level	The range of variation of the factors			
	X_1	X_2	X_3	X_4
Name indicators'	The graininess of the circle, 10^{-6}m	Circle hardness, conventional unit	Longitudinal feed, mm/rev.	The hardness of the workpiece, conventional unit
Basic level	230	3	0,0005	56
The range of variation in	20	1	0,0005	4
Top level	400	5	0,001	64
Lower level	60	1	0,0001	48

IV. METHODOLOGY

According to the existing recommendations [6], the cutting depth was equal to 0,04x10^{-3}m. In the experiments, blanks of plate knives from cold-rolled strips were used. The blanks were made of tool carbon steel U8A, 85HF,65G and were subjected to heat treatment, after which the hardness on the Rockwell scale ranged from 54 to 64 units. Dimensions of workpieces: length 0.25 m; a width of 0.02 m; the thickness of 0. 5x10^{-3} m.

Grinding wheels made of electrocorundum on a ceramic bond were used for sharpening. Sharpening of samples was carried out on a special device with the following characteristics: the speed of the circle – 20 m/s; type of sharpening: periphery of the circle; direction – across the blade, running; sharpening angle 17^0.

As the measured parameters characterizing the microrelief and the width of the cutting edge, the following parameters were used: R_{max} – the highest height of profile irregularities; R_a – the arithmetic mean deviation of the profile; R_p–the highest height of the protrusion; r – the average radius of the protrusion; h - the relative reference length along the middle line; S_m – the step of micro-irregularities along the middle line; a – the width of the cutting edge.

In the main series of experiments, the samples were studied on an automatic microscopic system, which includes in addition to a microscope with a photo attachment, a control panel with a screen, a display, a computer with a set of programs and a digital printer. The studies used two programs:

1) to determine the average width of the cutting edge;

2) to determine the parameters of the blade microrelief.

Measurements were made at 3 – 5 points along the length of the blade at 500-fold increase for the edge thickness and 1000 – fold increase – for the microrelief parameters, with the field of view of the microscope ranged from 160 to 380 microns, respectively. The average values of 180 points for the edge thickness and 370 points for the microrelief parameters were determined.

An attempt to obtain a linear equation based on the results of a four-factor experiment showed that the equation of this type does not adequately describe the process. Therefore, the mathematical model of the influence of the above factors on the microgeometry of the cutting edge is presented in the form of a power function:

$$y = b_0 \cdot t_1^{b_1} \cdot t_2^{b_2} \cdot t_3^{b_3} \cdot t_4^{b_4} \qquad (1)$$

where:
$$t_1 = \ln x_1;\ t_2 = \ln x_2$$
$$t_3 = \ln x_3;\ t_4 = \ln x_4$$

If $ln\ x = Z$ is denoted, the equation (1) takes the form:

$$Z = b_0 + b_1 \ln x_1 + b_2 \ln x_2 + b_3 \ln x_3 + b_4 \ln x_4 \qquad (2).$$

Calculation of the coefficients of this equation and its static analysis were performed according to known methods [4].

As a result of the experimental data processing and reduction of the coefficients to the dimensional form, the following regression equations were obtained:

$$\ln y_{R\max} = 3{,}216 + 1{,}157 \ln \frac{x_1}{154{,}9} + 0{,}109 \ln \frac{x_2}{2{,}236} - 0{,}005 \ln \frac{x_3}{0{,}0003} - 0{,}056 \ln \frac{x_4}{55}; \qquad (3)$$

$$\ln y_{Rp} = 2{,}575 + 1{,}031 \ln \frac{x_1}{154{,}9} + 0{,}118 \ln \frac{x_2}{2{,}236} - 0{,}020 \ln \frac{x_3}{0{,}0003} - 0{,}201 \ln \frac{x_4}{55}; \qquad (4)$$

$$\ln\ y_{Ra}=1{,}611+1{,}276\ln\frac{x_1}{154{,}9}+0{,}303\ln\frac{x_2}{2{,}236}-0{,}059\ln\frac{x_3}{0{,}0003}-1{,}145\ln\frac{x_4}{55};\qquad(5)$$

$$\ln\ y_{Rr}=3{,}709+0{,}522\ln\frac{x_1}{154{,}9}+0{,}113\ln\frac{x_2}{2{,}236}-0{,}027\ln\frac{x_3}{0{,}0003}-1{,}340\ln\frac{x_4}{55};\qquad(6)$$

$$\ln\ y_{Rs}=5{,}617+0{,}457\ln\frac{x_1}{154{,}9}+0{,}024\ln\frac{x_2}{2{,}236}-0{,}002\ln\frac{x_3}{0{,}0003}-0{,}194\ln\frac{x_4}{55};\qquad(7)$$

$$\ln\ y_{R\eta}=0{,}766+0{,}388\ln\frac{x_1}{154{,}9}+0{,}029\ln\frac{x_2}{2{,}236}-0{,}002\ln\frac{x_3}{0{,}0003}-0{,}688\ln\frac{x_4}{55};\qquad(8)$$

Analysis of the equations shows that the most significant factor affecting the microgeometry of the cutting edge is the grain of the grinding wheel. Further, the degree of importance of the input factors can be arranged in the following order: the hardness of the knife material, the hardness of the grinding wheel and the longitudinal feed.

A graphical interpretation of the equations obtained shows that an increase in the grit and hardness of the grinding wheel leads to a noticeable increase in all parameters except *r* and *h*. At the same time, there may be defects in sharpening – cauterization, blade inversions, Burr. Increasing the grain of the grinding wheel from 60x10^{-6} to 400x10^{-6} m leads to an increase in the width of the cutting edge by 30 – 40 %. The hardness of the grinding wheel on this parameter is virtually unaffected.

All controlled parameters, except the width of the cutting edge, with an increase in the initial hardness of the knives are reduced. Good results showed fine-tuning of the blade with a leather circle, with a paste of GOI applied to it. The finishing operation allows to reduce the height and step parameters of the microgeometry, reduce the width of the cutting edge by 10 – 15%. Changing the sharpening angle in the range 12 – 35^0 does not have a noticeable effect on the parameters of the microgeometry of the knives.

V. EXPERIMENTAL RESULTS

As a result of the experiments, it was found that the grain and hardness of the grinding wheel have a dominant influence on the parameters of the blade microgeometry. As a rational characteristics of the abrasive tool can be recommended grit 6, 10, 12, and hardness M1 and M2. Finishing the blade with leather circles can significantly improve the performance of *h* and *a*. This operation takes place with minimal heat, resulting in hardening of the treated surface due to the rivet. Fine-tuning on one side can cause distortion (bending) of the top of the blade due to processing forces, which is especially important at small angles of sharpening. With double-sided machining, the geometry is improved.

In general, it can be stated that the sharpening of the blade with an abrasive tool at the above modes corresponds to 7 – 8 quality accuracy and surface roughness R_a = *2,0–3,5* µm. Fine-tuning accuracy is achieved 5 – 6 quality and roughness R_a = *0,4 – 1,0* µm. In the subsequent series of experiments, the influence of fine-tuning of the cutting tool and the possibility of using modern abrasive materials for sharpening thin plate knives were studied.

Now for sharpening of the cutting tool the elboron which on hardness is close to diamond, but is more heat-resistant is more widely used [7]. Especially promising is the use of elboron for sharpening knives, because their grinding due to the increased content of vanadium and chromium with an ordinary abrasive tool is significantly worse: the carbides of these elements have the same hardness order as the electro-and monocorundum. Therefore, for sharpening knives were also used circles of elbora*PP 250x76x16x5 LOL 16S1K7 100%.*

The object of study in this section were knife plates (*d=0.4 mm*) of steel 85 ХФ, heat-treated for the hardness of HRS 46-48. Double-sided sharpening Angle was 15^0. Sharpening was carried out on the machine model 3Г71 around Э840СМ26К dry with the straightening of the wheel with a diamond pencil type. Grinding (lapping) of the chamfer made leather circles with the use of paste GOI. Initial parameters of sharpening were: grinding speed – 30 m/s; grit abrasive wheel – 10 – 40 µm; hardness – M1; speed of movement of the workpiece – 6 m/min, grinding depth – 0.08 mm.

The results of measuring the parameters of the microgeometry of plate knives are presented in table.2. These data are arithmetic means and are characterized by coefficients of variation: for parameters a, R_a, R_p, R_{max} – 10-12 %, for cm – 15 – 20%.

Table.1.

№	a µm	R_a µm	R_p µm	R_{max} µm	S_m µm	b	N
1	-	2,1	4,8	8,7	15,7	2,2	1,9
2	18,8	8,3	10,5	24,5	82,1	2,5	3,1
3	7,8	3,9	6,7	13,0	126,6	-0,8*	6,3*
4	12,9	5,7	9,0	19,2	127,9	1,7	3,1
5	4,3	3,2	4,5	12,9	173,4	-0,4*	5,2*

For these blades, the values of the coefficients of the straight section of the reference curve K and C.

Samples indicated in the first column of the table under the numbers 1,2,3, etc., obtained under the following conditions: 1 – knife chamfer, sharpened under the above conditions; 2 – blade of the same sample; 3 – blade, sharpened circle of elbora at the above modes; 4 – blade, sharpened and brought on one face; 5 – blade, sharpened and brought on two faces.

Table 2. it is shown that sharpening without finishing gives the width of the cutting edge a several times greater than that of the blade brought on two faces. This is noticeable in the study of Micrography, where the dark band corresponds to the width of the cutting edge, and the micro-teeth are arranged in two parallel lines. As the fine-tuning is carried out, the micro-teeth are constantly displayed on one line along the blade. Between the height parameters of the microrelief (R_a, R_p, R_{max}) with varying modes of formation of the blade, there is an unambiguous correspondence.

The maximum height of R_{max}micro-teeth on the blade is 2-2.5 times higher than on the chamfer. This, in our opinion, is due to the imposition on the blade of two side microreliefs formed separately during grinding chamfers. The value of the longitudinal step *Sm* of asperities on the blade chamfer 5-8 times less than on the cutting edge. The use of fine-tuning one and two facets increases the *Sm*.

Comparison of surface geometry of the sample №3 with other samples shows that elboro sharpening compared to abrasive grinding of the chamfers provide more fine cutting edges, and smaller values of the parameters of a high-rise group.

At the same time, according to some indicators, a fairly close approach to the microrelief of the brought blades is seen. Subsequent experiments have shown that the fine-tuning of the faces of the cutting edge after the elboro sharpening leads to a blade insignificantly different (within the error of experiments) from the sample №5, the blade of which was sharpened and brought to the above modes.

The most informative from the point of view of describing the location of the micro-teeth of the blade is the structural characteristic-the curve of the support surface. The analysis of experimental support curves shows that the entire range of variation of *h* can be divided into three characteristic areas. Section 1 corresponds to the most prominent microtubules and can be described by the expression:

$$\eta = b \cdot \varepsilon^{\nu} \qquad (9)$$

where *b* and *n* are constant coefficients.

Micro-teeth of this section carry out cutting at large values of short-circuit and can wear out in the period of burnishing of the blade. This area is practically absent from the driven blades.

Section 2 covers the most numerous group of micro-teeth, and when a certain approximation $\varepsilon = h_1/R_{max}$ is reached, the area of the actual contact depends on it linearly:

$$\eta = K\left((1-\frac{h_1}{R_{\max}})+C\right) \qquad (10)$$

where K, C are constant coefficients.

The transition point of the curvilinear section 1 to the rectilinear 2 corresponds to the moment of contact of the material with the vertex of the smaller micro-tooth. Micro-teeth of the section 2 perform the main work of micro-cutting, because they have greater strength and sufficient height. Moreover, the larger the interval occupies a straight section and the smaller its angle to the horizontal, the more effectively the formation of the initial micro-incision is carried out, since micro-teeth in this case are characterized by greater uniformity in height. Section 3 of the reference curve characterizes a small part of the deepest depressions, which in the presence of a tangential component of the speed may not participate in the cutting process.

Fine-tuning and elboro sharpening change the form of the support curve of the blade, which is virtually no first curved section, and the second straight section of the dependence h = f(ε) for such blades are higher, which provides a large actual contact area at the same convergence. Coefficients of the curve of the reference surface (table.2) vary in a wide range. Values close to optimal are fixed for samples № 4,5.

VI.CONCLUSION

The analysis of the experimental data showed a consistent decrease in the roughness of the cutting edge when finishing on one and two faces. So, after finishing on the 2nd sides of the high-rise parameters of the cutting edge are reduced by 1.8–2.0 times. Results close to fine-tuning can be obtained by using elboro circles, which is explained by the high cutting properties and hardness of boron nitride. It is especially important in this case, the formation of micro-teeth of the blade in one line with a zero transverse step. Elboro grinding is more effective than finishing on one face.

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